THERMOTRON

MODEL 012003

INSTRUCTION MANUAL

IN THE BEGINNING
THERE IS PRICE

IN THE END,
THERE IS COST

As a businessman, you know there are certain things you would never buy on the basis of price alone.

And probably, way up near the top of that list are environmental facilities.

Thermotron doesn't sell test chambers on price. We sell on the value of experience, services, quality and performance.

These services and performance are designed to help you prevent and control losses of production and products; and losses are what determine ultimate cost.

That's why we don't just ask for the chance to QUOTE on your business. We want the chance to show you what we can be worth in the long run.

HOW TO SET THE OPERATOR'S CONTROLS

of

TEMPERATURE CONTROLLER 012003

PRELIMINARY INFORMATION

This controller was designed for use on environmental/reliability test equipment. Its temperature range is -125F to +375F. This type of equipment typically cycles between low and high temperature, -65F and +160F, for example. Hence, the controller is designed to operate both heating and cooling equipment.

Several of the Operator's Controls are calibrated in percent insted of degrees F. This is done because the response of the thermocouple is nonlinear. In general,

0% = -125F & 100% = +375F

. . . but 50% does not equal +125F. The temperature corresponding to 50% of span is actually +157.3F. You can see why on the thermocouple millivolts table:

+375F = +8.787mv	†11.793mv = 100%
+157.3F = +2.890mv	† 5.897mv = 50%
–125F = –3.006mv	† 0.000mv = 0%

† = input mv referred to -125F input

As a general rule, 1% = 5 degrees F. Near the low end of the range 1% will be equal to about 7 degrees, and on the high end 1% will be about equal to 4 degrees.

1. INITIAL SET UP

If you're starting from scratch, set the controls as follows:

HEAT P ZONE	–1%
HEAT RESET	0%
HIGH LIMIT	100%
COOL P ZONE	+1%
COOL RESET	0%
LOW LIMIT	0%
PULSE RATE	60PPM
MACH TIME OUT	30Sec
DEV SPAN	±5%

These settings should bring a typical system into the 'ball park'.

Now observe the performance of the system as it runs through its normal operating pattern. Not much can be done to speed up this process, since timing is part of the control problem. For instance, if the system is cold for six hours and then switches to a high temperature, part of the heat up performance will be due to the fact that the chamber liner will still be cold long after the air temperature reaches the high set point. So when setting up the controller, you have to duplicate this situation. Otherwise the performance during actual operation may turn out differantly than the performance during set up.

2. PROPORTIONAL ZONE ADJUSTMENTS

These adjustments control the width of the proportioning zones. The heat proportioning zone extends from the set point to some lower temperature. The cool proportioning zone extends from the set point to some higher temperature.

As the temperature moves through the proportioning zone towards the set point, the heating or cooling action will be throttled down. When the temperature is at the set point, the heating and cooling outputs will be zero. This points out one of the inherant limitations of proportional control action.

Suppose that the set point is +230F, and the heat loss at this high temperature is considerable (insulation leakage, etc.). How can this heat be replaced while holding the temperature at the set point?

With proportioning action alone, it can't. The result is that the termperatur will 'droop' below the set point. Control will be established at the point where the heat added is equal to the heat being lost. If the proportioning zone is five degrees wide and the required heating output is 20%, then the droop will be minus one degree (+229F). If the proportioning zone is twenty-five degrees wide, for this case the droop would be minus five degrees (+225F). This illustrates why the proportioning zones should always be set as narrow as possible.

When the proportioning zones are set TOO WIDE, the result will be that during heat ups and pull downs, the temperature will never reach the set point because the heating and cooling equipment will be throttled too much, too soon. Thereafter, there will be too much droop, and the response to load changes will be poor.

When the zones are set TOO NARROW, overshoot will occur at the ends of heat ups and pull downs. Thereafter, the temperature will probably cycle above and below the set point. This oscillation will slowly dampen out unless the zones are much too narrow, in which case it will continue indefinately. If the system ever does stabilize, small load changes might frequently trigger this same oscillatory control action.

3. RESET ADJUSTMENTS

You have to set the proportional zone adjustments to minimize overshoot and cycling at set point. If this results in too much droop, you can correct this by shifting the proportioning zones so that they overlap the set point. This is done with the reset adjustments.

For example, if the set point is +160F, but the control point is only +157F, turn the heat reset knob to about +.6% (1% = 5F). If the set point is -65F and the control point droops at -60F, set the cool reset at about -1%. This will bring the control point to the set point.

You can also move the proportional zones away from the set point. This you would do if you have trouble with heating and cooling bucking each other at the set point, as sometimes happens in systems which are difficult to control.

For instance, you might set the heat reset at -.2% and the cool reset at +.2%. This would create a dead zone of about 2 degrees with the set point centered in the middle of it. Note that this means that you'll have to live with a one degree droop, unless you can add a one degree 'fudge factor' to the set point.

4. LIMIT ADJUSTMENTS

The limit adjustments provide failsafe action for the controller. Whenever the temperature crosses either the high or low limit, the controller's outputs will all be clamped OFF.

If you want to shorten the controller's range to protect aginst set point tampering, or whatever, you may set these limits closer to your actual operating range. For example, if your lowest temperature is -65F and your highest temperature is +160F, you might set the low limit to -75F and the high limit to +170F. Refering to the % Span Tables:

+170F = 52.7%
- 75F = 7.4%

Realize that these limits are not capable of protecting your system aginst all types of failures. They will protect aginst certain types of controller failures, including open thermocouples, and they can help to protect aginst set point errors and faults. However, if the output of the controller, or something connected to it, should happen to fail in the ON condition, these limits can do nothing to prevent a run-away condition. Therefore, your system should include some redundant device(s) which offer added protection aginst failures of this type. Prior to operating the system you should see to it that such devices are properly set, and that they are in good working order.

5. PULSE RATE ADJUSTMENT

The proportioning action is achieved by controlling the length of time that the cooling and heating are ON during each of a consecutive train of timing intervals. The pulse rate adjustment actually controls the number of intervals per minute.

So far a control is concerned, the faster you pulse the system, the better. However, the maximum mileage on contactors and solenoid valves is measured in mechanical operations, so its not good practice to pulse the system faster than necessary to achieve good control.

To find this point, set the pulse rate at 120PPM and let the system stabilize. Then slow down the pulse rate in small incriments until the temperature just begins to cycle. This is the slowest pulse rate that you will be able to run. This rate might be differant for cooling and heating. If so, set the knob at the faster rate.

6. MACHINE TIME OUT ADJUSTMENT

This circuit controls the operation of the refrigeration equipment so that it does not have to turn on and off as the cooling valve is pulsed.

You may set this knob at 120 seconds. If you want the machinery to turn off faster following periods of cooling operation, shorten the delay as desired. But do not decrease the delay to the point where the machinery cycles on and off during normal cooling operations, since this may shorten the life of the equipment.

7. DEVIATION SPAN ADJUSTMENT

This adjustment controls the sensitivity of the control indicator (deviation meter), if one is provided with the system. When set at ±5%, the meter range is about ±25F, full scale. At 0%, the full scale meter range is about ±.33F. This setting is strictly a matter of preferance.

IN CASE OF DIFFICULTY –

If you have a great deal of trouble in achieving reasonable performance, there's probably nothing wrong with either you or the controller.

Poor control is usually due to late information at the controller. In other words, the controller has to be kept up to date all the time – a few seconds delay can seriously degrade performance.

This means that the response of the sensor has to be fast, and the sensor has to be well located in the air stream. A sheathed sensor won't work because its not fast enough. Likewise, a poorly constructed bare thermocouple will also cause problems. At least four inches of insulation should be stripped away from the junction of the thermocouple, and this entire sensitive length should be well exposed to the air stream. Any clamps or fittings should be at least six inches away from the junction, and preferably loose fitting – not clamped down tightly on the wire. If the sensor is located in a 'dead spot', or shaded by another sensor, this can also appear as poor sensor response.

In test systems, this is usually the problem. Lags associated with the air flow rate do not usually cause problems, except in ducted air supplies which operate at very low exhaust velocity. The response of the heating

and cooling equipment is not usually a factor, except with regard to the initializing of the cooling system when it first turns on after having been off long enough to 'loose its prime'. If this becomes a problem, set the machine time out delay at 120 seconds then, if necessary, increase the cooling proportioning zone.

If you're useing a temperature recorder to monitor control performance, be sure that the recorder is telling the truth prior to readjusting the controller. What looks like 'undershoot', slow response to small load variations or a slow temperature drift, might well be attributable to the recorder and its sensor. The response of the controller, when properly applied and adjusted, is likely to be equal or better than that of an associated temperature recorder. This is especially true if the recorder is equipped with a platinum resistance temperature sensor – which many prefer in the interest of theoretical accuracy. When adjusting the controller, its generally better to monitor the control indicator (deviation meter), than to rely exclusively upon a recorder.

% SPAN TABLES

FOR PRECISION DIGITAL SET POINTS

COPPER VS. COPPER-NICKEL
(COPPER-CONSTANTAN)

TEMPERATURE IN DEGREES F — RANGE -125° TO +375°F

PERCENT OF ABSOLUTE MILLIVOLT SPAN

DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
-120	.0070	.0057	.0042	.0028	.0014	.0000						-120
-110	.0215	.0199	.0185	.0170	.0156	.0143	.0128	.0114	.0099	.0085	.0070	-110
-100	.0360	.0346	.0331	.0316	.0302	.0288	.0272	.0258	.0243	.0229	.0215	-100
- 90	.0510	.0495	.0480	.0465	.0450	.0435	.0420	.0405	.0390	.0376	.0360	- 90
- 80	.0662	.0647	.0632	.0617	.0601	.0586	.0571	.0555	.0540	.0525	.0510	- 80
- 70	.0817	.0801	.0786	.0770	.0755	.0739	.0724	.0708	.0693	.0678	.0662	- 70
- 60	.0975	.0959	.0943	.0928	.0912	.0895	.0880	.0864	.0849	.0833	.0817	- 60
- 50	.1135	.1119	.1103	.1087	.1071	.1055	.1039	.1023	.1007	.0990	.0975	- 50
- 40	.1298	.1282	.1266	.1249	.1233	.1217	.1200	.1184	.1168	.1152	.1135	- 40
- 30	.1464	.1447	.1431	.1414	.1397	.1381	.1364	.1348	.1331	.1315	.1298	- 30
- 20	.1632	.1615	.1598	.1581	.1565	.1548	.1531	.1514	.1497	.1481	.1464	- 20
- 10	.1804	.1787	.1769	.1752	.1735	.1718	.1701	.1683	.1666	.1649	.1632	- 10
0	.1977	.1960	.1942	.1925	.1907	.1890	.1872	.1855	.1838	.1821	.1804	0
0	.1977	.1994	.2012	.2029	.2047	.2065	.2083	.2100	.2117	.2135	.2153	0
10	.2153	.2171	.2189	.2206	.2224	.2242	.2260	.2278	.2295	.2314	.2332	10
20	.2332	.2350	.2368	.2385	.2404	.2422	.2440	.2458	.2476	.2495	.2513	20
30	.2513	.2530	.2549	.2568	.2585	.2604	.2622	.2641	.2659	.2677	.2696	30
40	.2696	.2714	.2732	.2751	.2769	.2788	.2806	.2825	.2843	.2862	.2881	40
50	.2881	.2899	.2913	.2936	.2955	.2974	.2992	.3011	.3030	.3048	.3067	50
60	.3067	.3087	.3105	.3124	.3143	.3161	.3181	.3199	.3218	.3238	.3256	60
70	.3256	.3276	.3294	.3314	.3332	.3352	.3371	.3390	.3409	.3428	.3448	70
80	.3448	.3466	.3486	.3505	.3525	.3544	.3563	.3583	.3602	.3622	.3641	80
90	.3641	.3661	.3680	.3700	.3719	.3739	.3758	.3778	.3797	.3817	.3836	90
100	.3836	.3857	.3876	.3896	.3915	.3935	.3955	.3974	.3995	.4014	.4035	100
110	.4035	.4054	.4074	.4094	.4114	.4134	.4154	.4175	.4194	.4214	.4235	110
120	.4235	.4254	.4275	.4295	.4315	.4336	.4356	.4375	.4396	.4416	.4437	120
130	.4437	.4457	.4477	.4498	.4518	.4539	.4559	.4580	.4600	.4621	.4641	130
140	.4641	.4662	.4682	.4703	.4724	.4744	.4765	.4786	.4806	.4827	.4848	140
150	.4848	.4869	.4889	.4911	.4931	.4952	.4973	.4994	.5015	.5036	.5057	150
160	.5057	.5078	.5099	.5120	.5141	.5162	.5184	.5204	.5225	.5246	.5268	160
170	.5268	.5289	.5310	.5331	.5353	.5374	.5396	.5417	.5438	.5459	.5481	170
180	.5481	.5502	.5524	.5545	.5567	.5588	.5609	.5631	.5653	.5675	.5696	180
190	.5696	.5718	.5739	.5761	.5782	.5804	.5825	.5848	.5870	.5891	.5913	190
200	.5913	.5935	.5957	.5978	.6000	.6022	.6044	.6066	.6088	.6110	.6132	200
210	.6132	.6154	.6176	.6198	.6220	.6242	.6264	.6287	.6309	.6331	.6353	210
220	.6353	.6375	.6397	.6420	.6442	.6464	.6486	.6509	.6531	.6553	.6576	220
230	.6576	.6598	.6620	.6643	.6665	.6688	.6710	.6733	.6755	.6778	.6801	230
240	.6801	.6823	.6846	.6868	.6891	.6913	.6936	.6958	.6981	.7004	.7027	240
250	.7027	.7049	.7072	.7095	.7118	.7141	.7164	.7186	.7209	.7232	.7255	250
260	.7255	.7278	.7301	.7324	.7347	.7370	.7393	.7415	.7439	.7462	.7485	260
270	.7485	.7508	.7531	.7554	.7577	.7600	.7624	.7647	.7670	.7694	.7716	270
280	.7716	.7740	.7763	.7787	.5520	.7833	.7856	.7880	.7903	.7927	.7950	280
290	.7950	.7973	.7997	.8020	.8044	.8067	.8091	.8114	.8138	.8162	.8185	290
300	.8185	.8209	.8232	.8256	.8279	.8303	.8327	.8351	.8374	.8398	.8422	300
310	.8422	.8446	.8469	.8493	.8517	.8541	.8564	.8588	.8613	.8636	.8660	310
320	.8660	.8684	.8708	.8732	.8756	.8780	.8804	.8828	.8852	.8876	.8900	320
330	.8900	.8924	.8949	.8972	.8997	.9021	.9045	.9069	.9094	.9117	.9142	330
340	.9142	.9166	.9190	.9215	.9239	.9263	.9288	.9311	.9336	.9361	.9385	340
350	.9385	.9409	.9434	.9458	.9483	.9507	.9532	.9557	.9580	.9605	.9629	350
360	.9629	.9654	.9678	.9703	.9728	.9752	.9777	.9802	.9827	.9852	.9876	360
370	.9876	.9901	.9925	.9950	.9975	.9999						370
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F

TYPE T PER ASA C96.1-1971

*CONVERTED FROM ASA TEMP. VS. EMF TABLES (THERMOTRON 1972)

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% SPAN TABLES

FOR PRECISION DIGITAL SET POINTS

COPPER VS. COPPER-NICKEL
(COPPER-CONSTANTAN)

TYPE T

TEMPERATURE IN DEGREES C — RANGE -87°C TO +190°C

PERCENT OF ABSOLUTE MILLIVOLT SPAN

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
- 80	.0185	.0159	.0133	.0108	.0082	.0057	.0031	.0006				- 80
- 70	.0450	.0423	.0396	.0370	.0343	.0316	.0290	.0264	.0237	.0211	.0185	- 70
- 60	.0724	.0696	.0668	.0641	.0613	.0586	.0558	.0531	.0504	.0477	.0450	- 60
- 50	.1007	.0978	.0950	.0921	.0893	.0864	.0836	.0808	.0779	.0751	.0724	- 50
- 40	.1298	.1269	.1240	.1210	.1180	.1152	.1123	.1093	.1064	.1035	.1007	- 40
- 30	.1598	.1568	.1538	.1508	.1478	.1447	.1418	.1387	.1358	.1328	.1298	- 30
- 20	.1907	.1876	.1845	.1814	.1783	.1752	.1721	.1690	.1659	.1629	.1598	- 20
- 10	.2224	.2192	.2160	.2128	.2096	.2065	.2033	.2001	.1970	.1938	.1907	- 10
0	.2549	.2516	.2483	.2450	.2418	.2385	.2353	.2321	.2288	.2256	.2224	0
0	.2549	.2582	.2615	.2648	.2681	.2714	.2747	.2780	.2813	.2846	.2880	0
10	.2880	.2913	.2947	.2981	.3014	.3048	.3082	.3116	.3150	.3184	.3218	10
20	.3218	.3253	.3286	.3321	.3355	.3390	.3424	.3459	.3493	.3528	.3563	20
30	.3563	.3598	.3633	.3668	.3703	.3738	.3773	.3809	.3844	.3879	.3915	30
40	.3915	.3950	.3986	.4022	.4058	.4094	.4130	.4166	.4202	.4238	.4274	40
50	.4274	.4311	.4347	.4384	.4420	.4457	.4494	.4530	.4567	.4604	.4640	50
60	.4640	.4678	.4715	.4752	.4790	.4827	.4864	.4902	.4939	.4977	.5014	60
70	.5014	.5053	.5090	.5128	.5166	.5203	.5242	.5280	.5318	.5357	.5395	70
80	.5395	.5433	.5471	.5510	.5549	.5588	.5627	.5666	.5704	.5743	.5782	80
90	.5782	.5821	.5861	.5900	.5939	.5978	.6017	.6056	.6096	.6136	.6175	90
100	.6175	.6215	.6255	.6295	.6335	.6374	.6414	.6455	.6495	.6535	.6575	100
110	.6576	.6616	.6656	.6696	.6737	.6778	.6818	.6859	.6900	.6941	.6981	110
120	.6981	.7022	.7064	.7104	.7145	.7186	.7227	.7269	.7310	.7351	.7393	120
130	.7393	.7434	.7476	.7517	.7559	.7600	.7643	.7684	.7726	.7768	.7810	130
140	.7810	.7852	.7894	.7936	.7978	.8020	.8062	.8105	.8147	.8190	.8232	140
150	.8232	.8275	.8318	.8360	.8402	.8446	.8488	.8531	.8575	.8617	.8660	150
160	.8660	.8703	.8746	.8789	.8833	.8876	.8919	.8962	.9006	.9049	.9093	160
170	.9093	.9136	.9180	.9223	.9268	.9311	.9355	.9399	.9443	.9487	.9531	170
180	.9531	.9575	.9619	.9663	.9708	.9752	.9797	.9841	.9885	.9930	.9974	180
190	.9974											190
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

TYPE T PER ASA C96.1-1971

*CONVERTED FROM ASA TEMP. VS. EMF TABLES (THERMOTRON 1972)

THERMOTRON CORPORATION
338 WEST TWELFTH STREET, HOLLAND, MICHIGAN 49423
(616) 392-1492 / TWX (810) 292-6164

THERMOTRON

REGISTERED T. M. THERMOTRON CORP.

COPPER vs. COPPER-NICKEL

(Copper-Constantan)

TYPE T

Temperature in Degrees F

Reference Junction at 32°F

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
-190	-4.009	-4.023	-4.037	-4.051	-4.065	-4.079	-4.093	-4.107	-4.121	-4.135	-4.149	-190
-180	-3.864	-3.879	-3.894	-3.908	-3.923	-3.937	-3.951	-3.966	-3.980	-3.994	-4.009	-180
-170	-3.717	-3.732	-3.746	-3.761	-3.776	-3.791	-3.806	-3.820	-3.835	-3.850	-3.864	-170
-160	-3.565	-3.580	-3.596	-3.611	-3.626	-3.641	-3.656	-3.671	-3.687	-3.702	-3.717	-160
-150	-3.410	-3.425	-3.441	-3.457	-3.472	-3.488	-3.503	-3.519	-3.534	-3.550	-3.565	-150
-140	-3.251	-3.267	-3.283	-3.299	-3.315	-3.331	-3.347	-3.362	-3.378	-3.394	-3.410	-140
-130	-3.089	-3.105	-3.121	-3.138	-3.154	-3.170	-3.186	-3.203	-3.219	-3.235	-3.251	-130
-120	-2.923	-2.939	-2.956	-2.973	-2.989	-3.006	-3.023	-3.039	-3.056	-3.072	-3.089	-120
-110	-2.753	-2.771	-2.788	-2.805	-2.822	-2.838	-2.855	-2.872	-2.889	-2.906	-2.923	-110
-100	-2.581	-2.598	-2.616	-2.633	-2.650	-2.667	-2.685	-2.702	-2.719	-2.736	-2.753	-100
-90	-2.405	-2.422	-2.440	-2.458	-2.475	-2.493	-2.511	-2.528	-2.546	-2.563	-2.581	-90
-80	-2.225	-2.243	-2.261	-2.279	-2.297	-2.315	-2.333	-2.351	-2.369	-2.387	-2.405	-80
-70	-2.042	-2.061	-2.079	-2.098	-2.116	-2.134	-2.152	-2.171	-2.189	-2.207	-2.225	-70
-60	-1.856	-1.875	-1.894	-1.912	-1.931	-1.950	-1.968	-1.987	-2.005	-2.024	-2.042	-60
-50	-1.667	-1.686	-1.705	-1.724	-1.743	-1.762	-1.781	-1.800	-1.819	-1.838	-1.856	-50
-40	-1.475	-1.494	-1.513	-1.533	-1.552	-1.571	-1.591	-1.610	-1.629	-1.648	-1.667	-40
-30	-1.279	-1.299	-1.319	-1.338	-1.358	-1.377	-1.397	-1.416	-1.436	-1.455	-1.475	-30
-20	-1.081	-1.101	-1.121	-1.141	-1.160	-1.180	-1.200	-1.220	-1.240	-1.260	-1.279	-20
-10	-0.879	-0.899	-0.920	-0.940	-0.960	-0.980	-1.000	-1.021	-1.041	-1.061	-1.081	-10
0	-0.674	-0.695	-0.716	-0.736	-0.757	-0.777	-0.798	-0.818	-0.838	-0.859	-0.879	0
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F
0	-0.674	-0.654	-0.633	-0.613	-0.592	-0.571	-0.550	-0.529	-0.509	-0.488	-0.467	0
10	-0.467	-0.446	-0.425	-0.404	-0.383	-0.362	-0.341	-0.320	-0.299	-0.277	-0.256	10
20	-0.256	-0.235	-0.214	-0.193	-0.171	-0.150	-0.129	-0.107	-0.086	-0.064	-0.043	20
30	-0.043	-0.022	0.000	0.022	0.043	0.065	0.086	0.108	0.130	0.151	0.173	30
40	0.173	0.195	0.216	0.238	0.260	0.282	0.303	0.325	0.347	0.369	0.391	40
50	0.391	0.413	0.435	0.457	0.479	0.501	0.523	0.545	0.567	0.589	0.611	50
60	0.611	0.634	0.656	0.678	0.700	0.722	0.745	0.767	0.789	0.812	0.834	60
70	0.834	0.857	0.879	0.902	0.924	0.947	0.969	0.992	1.014	1.037	1.060	70
80	1.060	1.082	1.105	1.128	1.151	1.173	1.196	1.219	1.242	1.265	1.288	80
90	1.288	1.311	1.334	1.357	1.380	1.403	1.426	1.449	1.472	1.495	1.518	90
100	1.518	1.542	1.565	1.588	1.611	1.635	1.658	1.681	1.705	1.728	1.752	100
110	1.752	1.775	1.799	1.822	1.846	1.869	1.893	1.917	1.940	1.964	1.988	110
120	1.988	2.011	2.035	2.059	2.083	2.107	2.131	2.154	2.178	2.202	2.226	120
130	2.226	2.250	2.274	2.298	2.322	2.347	2.371	2.395	2.419	2.443	2.467	130
140	2.467	2.492	2.516	2.540	2.565	2.589	2.613	2.638	2.662	2.687	2.711	140
150	2.711	2.736	2.760	2.785	2.809	2.834	2.859	2.883	2.908	2.933	2.958	150
160	2.958	2.982	3.007	3.032	3.057	3.082	3.107	3.131	3.156	3.181	3.206	160
170	3.206	3.231	3.256	3.281	3.307	3.332	3.357	3.382	3.407	3.432	3.458	170
180	3.458	3.483	3.508	3.533	3.559	3.584	3.609	3.635	3.660	3.686	3.711	180
190	3.711	3.737	3.762	3.788	3.813	3.839	3.864	3.890	3.916	3.941	3.967	190
200	3.967	3.993	4.019	4.044	4.070	4.096	4.122	4.148	4.174	4.199	4.225	200
210	4.225	4.251	4.277	4.303	4.329	4.355	4.381	4.408	4.434	4.460	4.486	210
220	4.486	4.512	4.538	4.565	4.591	4.617	4.643	4.670	4.696	4.722	4.749	220
230	4.749	4.775	4.801	4.828	4.854	4.881	4.907	4.934	4.960	4.987	5.014	230
240	5.014	5.040	5.067	5.093	5.120	5.147	5.174	5.200	5.227	5.254	5.281	240
250	5.281	5.307	5.334	5.361	5.388	5.415	5.442	5.469	5.496	5.523	5.550	250
260	5.550	5.577	5.604	5.631	5.658	5.685	5.712	5.739	5.767	5.794	5.821	260
270	5.821	5.848	5.875	5.903	5.930	5.957	5.985	6.012	6.039	6.067	6.094	270
280	6.094	6.122	6.149	6.177	6.204	6.232	6.259	6.287	6.314	6.342	6.369	280
290	6.369	6.397	6.425	6.452	6.480	6.508	6.536	6.563	6.591	6.619	6.647	290
300	6.647	6.675	6.702	6.730	6.758	6.786	6.814	6.842	6.870	6.898	6.926	300
310	6.926	6.954	6.982	7.010	7.038	7.066	7.094	7.122	7.151	7.179	7.207	310
320	7.207	7.235	7.263	7.292	7.320	7.348	7.377	7.405	7.433	7.462	7.490	320
330	7.490	7.518	7.547	7.575	7.604	7.632	7.661	7.689	7.718	7.746	7.775	330
340	7.775	7.804	7.832	7.861	7.889	7.918	7.947	7.975	8.004	8.033	8.062	340
350	8.062	8.090	8.119	8.148	8.177	8.206	8.235	8.264	8.292	8.321	8.350	350
360	8.350	8.379	8.408	8.437	8.466	8.495	8.524	8.553	8.583	8.612	8.641	360
370	8.641	8.670	8.699	8.728	8.757	8.787	8.816	8.845	8.874	8.904	8.933	370
380	8.933	8.962	8.992	9.021	9.050	9.080	9.109	9.139	9.168	9.198	9.227	380
390	9.227	9.257	9.286	9.316	9.345	9.375	9.404	9.434	9.464	9.493	9.523	390
400	9.523	9.553	9.582	9.612	9.642	9.671	9.701	9.731	9.761	9.791	9.820	400
410	9.820	9.850	9.880	9.910	9.940	9.970	10.000	10.030	10.060	10.090	10.120	410
420	10.120	10.150	10.180	10.210	10.240	10.270	10.300	10.330	10.360	10.390	10.420	420
430	10.420	10.451	10.481	10.511	10.541	10.572	10.602	10.632	10.662	10.693	10.723	430
440	10.723	10.753	10.784	10.814	10.845	10.875	10.905	10.936	10.966	10.997	11.027	440
450	11.027	11.058	11.088	11.119	11.149	11.180	11.211	11.241	11.272	11.302	11.333	450
460	11.333	11.364	11.396	11.425	11.456	11.487	11.517	11.548	11.579	11.610	11.640	460
470	11.640	11.671	11.702	11.733	11.764	11.795	11.826	11.856	11.887	11.918	11.949	470
480	11.949	11.980	12.011	12.042	12.073	12.104	12.135	12.166	12.198	12.229	12.260	480
490	12.260	12.291	12.322	12.353	12.384	12.416	12.447	12.478	12.509	12.540	12.572	490
500	12.572	12.603	12.634	12.666	12.697	12.728	12.760	12.791	12.822	12.854	12.885	500
510	12.885	12.917	12.948	12.979	13.011	13.042	13.074	13.105	13.137	13.168	13.200	510
520	13.200	13.232	13.263	13.295	13.326	13.358	13.390	13.421	13.453	13.485	13.516	520
530	13.516	13.548	13.580	13.611	13.643	13.675	13.707	13.739	13.770	13.802	13.834	530
540	13.834	13.866	13.898	13.930	13.961	13.993	14.025	14.057	14.089	14.121	14.153	540
550	14.153	14.185	14.217	14.249	14.281	14.313	14.345	14.377	14.409	14.441	14.474	550
560	14.474	14.506	14.538	14.570	14.602	14.634	14.666	14.699	14.731	14.763	14.795	560
570	14.795	14.828	14.860	14.892	14.924	14.957	14.989	15.021	15.054	15.086	15.118	570
580	15.118	15.151	15.183	15.216	15.248	15.280	15.313	15.345	15.378	15.410	15.443	580
590	15.443	15.475	15.508	15.540	15.573	15.605	15.638	15.671	15.703	15.736	15.769	590
600	15.769	15.801	15.834	15.866	15.899	15.932	15.965	15.997	16.030	16.063	16.096	600
610	16.096	16.128	16.161	16.194	16.227	16.259	16.292	16.325	16.358	16.391	16.424	610
620	16.424	16.457	16.490	16.523	16.555	16.588	16.621	16.654	16.687	16.720	16.753	620
630	16.753	16.786	16.819	16.852	16.886	16.919	16.952	16.985	17.018	17.051	17.084	630
640	17.084	17.117	17.150	17.184	17.217	17.250	17.283	17.316	17.350	17.383	17.416	640
650	17.416	17.450	17.483	17.516	17.549	17.583	17.616	17.649	17.683	17.716	17.750	650
660	17.750	17.783	17.816	17.850	17.883	17.917	17.950	17.984	18.017	18.051	18.084	660
670	18.084	18.118	18.151	18.185	18.218	18.252	18.285	18.319	18.353	18.386	18.420	670
680	18.420	18.454	18.487	18.521	18.555	18.588	18.622	18.656	18.689	18.723	18.757	680
690	18.757	18.791	18.824	18.858	18.892	18.926	18.960	18.993	19.027	19.061	19.095	690
700	19.095	19.129	19.163	19.197	19.230	19.264	19.298	19.332	19.366	19.400	19.434	700
710	19.434	19.468	19.502	19.536	19.570	19.604	19.638	19.672	19.706	19.740	19.774	710
720	19.774	19.808	19.843	19.877	19.911	19.945	19.979	20.013	20.047	20.081	20.116	720
730	20.116	20.150	20.184	20.218	20.252	20.287	20.321	20.355	20.389	20.423	20.458	730
740	20.458	20.492	20.526	20.560	20.595	20.629	20.663	20.698	20.732	20.766	20.801	740
750	20.801	20.835	20.869									750
DEG F	0	1	2	3	4	5	6	7	8	9	10	DEG F

* CONVERTED FROM DEGREES C(IPTS 1968).

TYPE T

NEW REFERENCE TABLES
SUPERSEDES N.B.S. CIRCULAR #561

FIELD CALIBRATION PROCEDURES

for

TEMPERATURE CONTROLLER 012003

PRELIMINARY INFORMATION

The 012003 controller has seventeen trimming adjustments in addition to its nine Operator's Controls. Twelve of these trimpots are 'factory adjustments'. These will not normally require further adjustment in the field. The five remaining adjustments should be checked periodically in the field, in order to assure that the controller remains fairly accurate. These adjustments are covered in the following procedure.

The equipment that is required in order to do these adjustments is indicated on our drawing 470270.

Those who wish to do a complete check of the controller in their metrology lab or service shop, should refer to the ALLIGNMENT, CALIBRATION & MINIMUM PERFORMANCE CHECKS, which follows this procedure.

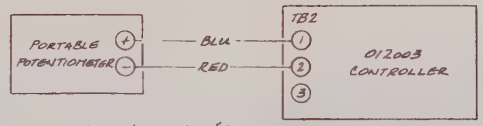
WARNING

An electrical potential of 115 volts AC at 50-60 Hz is present on the circuit board in the area of the transformer and the terminal block marked TB1. Keep your hands and tools away from this area. Should any part of your body come into contact with this potential, you might be seriously injured, directly or indirectly, as a result of

ELECTRICAL SHOCK

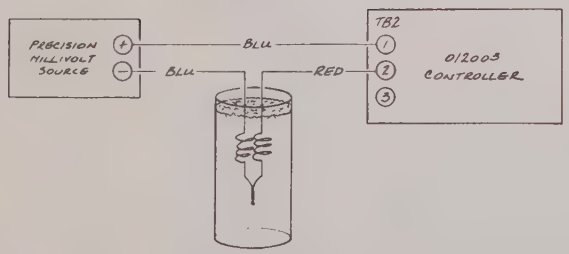
In the remaining areas of the circuit board low DC voltages [less than 30vdc] are less hazardous to life, however short circuiting these potentials might result in permanent damage to the controller. So be careful when useing screwdrivers and test probes.

SET UP #2



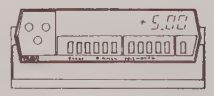
If you have a good "Portable", a Honeywell 2734 or better, and if it is properly maintained, this set up can be as accurate as #1. Since the portable compensates automatically for the junction formed at its (−) terminal, this set up is the most convenient and the least time consuming.

SET UP #1



Melting crushed ice saturated with water. At least six inches of the thermocouple should be submerged in the center of this bath, not touching the bottom or sides of the container.

0°C/+32°F is defined as the temperature at which water freezes, or ice melts. Most thermocouple calibration tables are referenced to this point, because it is fairly easy to reproduce with a high degree of accuracy.



Digital Voltmeter

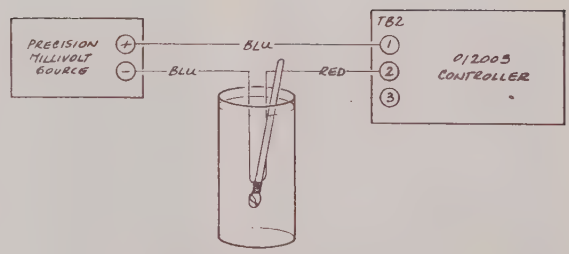
All of our alignment & calibration procedures call for the use of a DVM, a Fluke model 8000A or equal. Never use a VTVM with an analog meter, or a regular voltmeter. The accuracy of such meters is not typically better than 1% to 2%, which corresponds to errors as large as ±10°F. The accuracy of the 8000A is about ±.1%.

Refer to the written procedures for step by step instructions on how to calibrate the controller.

When making the above wiring connections, use only copper vs constantan thermocouple wire:

Blue = copper (+)
Red = constantan (−)

SET UP #3



Wrap a thermocouple around a good mercury thermometer and submerge at least six inches of the wire into water. Allow the bath to stabilize at room temperature prior to use.

If carefully done, this set up can approach the accuracy of #1 or #2. You must use an accurate thermometer, since any error there will be included directly in your calibration.

THERMOTRON CORPORATION HOLLAND, MICHIGAN 49423	NO.	CHANGES	DATE	BY	CH'K'D	NO.	CHANGES	DATE	BY	CH'K'D	TOLERANCE SCALE MATERIAL FINISH DRAWN BY KWERNER DATE 8/27/73 CHECKED BY DATE RELEASED BY DATE	DESCRIPTION CONTROLLER CALIBRATION SET UPS REF: 012003 470270

1. POWER SUPPLY ADJUSTMENTS

The controller power supply includes a +15v regulated supply and a -15v regulated supply. These two supplies are used to provide referance voltages at several points in the controller circuitry, so its important that they be properly adjusted.

1.1. Connect the DVM [+] lead to R82 [orange-black-gold-gold] on the end marked [+]. Connect the DVM [-] lead to TB2, terminal 1.

1.2. The DVM indication should now be +15.00v. If not, adjust R84 as necessary to produce this indication.

1.3. Now connect the DVM [+] lead to the case of IC5.

1.4. The DVM indication should now be -15.00v. If not, adjust R86 as necessary to make it -15.00v.

2. RJC CHECK

The accuracy of the controller's temperature measurement depends upon the proper operation of its referance junction compensator circuit. So the operation of this circuit should be checked.

2.1. Connect the DVM [+] lead to the right-hand end of R5, right next to the '2' of the legend 'TB2'.

2.2. The DVM indication should alternate between about -0.4v and +13.5v at a rate of about 1½ cycles per second. If 'stuck' at either extreme, the RJC circuit is not operating properly and the controller should be removed for service.

3. TEMPERATURE ZERO & SPAN CALIBRATION

The controller measures temperature by means of a thermocouple sensor. This measurement can be very accurate when the measuring circuits are properly calibrated. In order to control accurately the measurement must, obviously, be accurate.

A few precautions:

- These controllers have the capability of driving temperature indicators. If the system has such an indicator, it must be calibrated separately later on. For the time being, ignore it.

- A thermocouple is made by connecting the ends of two dissimilar wires; in this case, copper and constantan. Where the dissimilar wires touch, a temperature sensitive junction is formed.

Differant types of materials give a differant response. Therefore, in the following procedure you must use copper and constantan thermocouple wire ONLY. Otherwise, your calibration will be wrong.

- Refer to our drawing 470270. Here we show the three possible calibration set ups. One of these, and none others, must be used. The order of preferance is indicated on the drawing. The point is, all junctions in the sensor wiring must be accounted for, since they are all temperature sensitive. When this is not done, significant errors will result, and it might even be impossible to calibrate the controller.

- If the controller is installed and wired into heating and cooling equipment, positively disable this equipment before you proceed. During this procedure you will be feeding false temperature information to the controller, and this could result in unsafe operation of any associated heating and cooling equipment.

- You will temporarily disconnect the controller's thermocouple sensor. When finished with the calibration, be sure that it is properly reconnected, else the controller will not operate properly.

3.1. Disconnect the controller's thermocouple at TB2, terminals 1 and 2. In its place, connect the extension wires from your calibration set up:

TB2-1: + [copper] BLUE insulated wire
TB2-2: – [constantan] RED insulated wire

Notice the small constantan wire which is permanently connected to TB2-2. Your constantan wire should physically touch this wire.

3.2. Connect the DVM [+] lead to TB3, terminal 9. Then connect the DVM [-] lead to TB3, terminal 7.

3.3. Now adjust your set up as follows:

Set Up 1: Set the millivolt source at exactly -3.006mv.

Set Up 2: Set the portable potentiometer at exactly -125F, or -3.006mv.

Set Up 3: Read the temperature of the water without disturbing the thermometer. Refer to the 'T' table and find the millivolt value corresponding to that temperature. Algebraically subtract this value from -3.006mv, and set the millivolt source to this corrected value.

[example on next page]

Example: 75F water = 0.947mv

thus, -3.006mv
-0.947mv
-3.953mv

3.4. The DVM should now indicate 0.000v. If not, adjust R13 as necessary to achieve this indication.

3.5. Now readjust your set up:

Set Up 1: Set the millivolt source at exactly +8.787mv.

Set Up 2: Set the portable potentiometer at exactly +375F, or +8.787mv.

Set Up 3: Read the water temperature without disturbing the thermometer. Again refer to the 'T' table and find the millivolt value corresponding to that temperature. Subtract this value from +8.787mv, and set the millivolt source to this corrected value.

Example: 75F water = 0.947mv

thus, +8.787mv
-0.947mv
+7.840mv

3.6. The DVM should now indicate +5.00v. If not, adjust R19 as necessary to achieve this indication.

3.7. Unless you have a temperature indicating device in your system, disconnect your test set up, and reconnect the controller's thermocouple sensor:

TB2-1: + [copper] BLUE insulated wire
TB2-2: – [constantan] RED insulated wire

4. TEMPERATURE INDICATOR CALIBRATION

If your system includes a temperature indicating meter, it is nost likely a Thermotron Model 013005. If it is some other type, you will have to extrapolate these instructions to that device if it has no instructions of its own.

4.1. Vary the setting of your test set up until the DVM reads 0.000v. Now adjust the mechanical zero adjustment on the front of the meter so that its pointer indicates exactly -125F.

4.2. Vary the setting of your test set up until the DVM reads +5.00v. Now adjust the electrical span adjustment on the back of the meter [R2] so that the pointer indicated exactly +375F.

5. SET POINT CALIBRATION

The set point is the controller's instruction. It tells the controller what temperature to control. The controller has no set point station of its own, but can supply power to remote set point potentiometers. This is the case when the 013005 Indicator/Set Point Assembly is used with the controller, or if a single potentiometer is used to establish the set point. If your system has some other set point source, refer to its instructions. Otherwise, proceed as follows.

5.1. Connect the DVM [+] lead to TB3, terminal 8, and its [-] lead to TB3, terminal 7.

5.2. Adjust the set point index to +375F. The DVM should now indicate +5.00v exactly. If not, adjust R22 as necessary to provide this indication.

NOTE: There is no zero adjustment for the set point on 013005 units. When the set point is moved to -125F, the DVM should read 0.00v. If not, the unit is defective. Where a single potentiometer is used as the set point adjustment, its knob should be mechanically zeroed prior to doing step 5.2.

ALLIGNMENT, CALIBRATION & MINIMUM PERFORMANCE CHECKS

for

TEMPERATURE CONTROLLER 012003

PRELIMINARY INFORMATION

The 012003 Controller is a precision device. As such, it includes several adjustments which serve to set circuit values to within closer tolerances than can be achieved through the selection of standard fixed componet values.

These adjustments are all rechecked, and reset if necessary, at the factory following burn in of the controller. Most of them should not require any attention in the field until, perhaps, after several years of operation, or unless they are inadvertantly disturbed, or if the device has been subjected to rough handling or severe vibration.

The FIELD CALIBRATION PROCEDURE covers those adjustments which should be checked as a normal part of field maintenance and service activities. For field activities that procedure should be used.

This procedure is intended for factory production and test, factory service, and bench level service at field repair stations. Units which can successfully meet these minimum performance requirements can be considered to be fully serviceable, and able to perform their designed functions within the limits of their specification.

EQUIPMENT REQUIRED

1. Digital Voltmeter, Fluke Model 8000A, or equal
   [Do not attempt to use a VOM or VTVM since the accuracy of analog type meters is not satisfactory for this procedure.]
2. Oscilloscope, Tektronix 212, or equal.
3. Precision Voltage Source, Thermotron 434004, or equal.
4. Portable Potentiometer, Honeywell Model 2736, or equal.
5. Variac, Superior Electric 116B, or equal.
6. Resistor, 330 Ohms, ¼w, 5%.
7. Resistor, 1.5K, ¼w, 5%.
8. Stop Watch, Galco Model 955, or equal.

GENERAL PROCEDURE

This procedure works through the controller circuitry in the following order:

1. D.C. POWER SUPPLY & REGULATOR CIRCUITS
2. REFERANCE JUNCTION COMPENSATOR CKT
3. AMPLIFIER & SCALEING CIRCUITS
4. SET POINT BUFFER & DEVIATION AMP CKTS
5. PROPORTIONING WAVE GENERATOR CKTS
6. HEAT PROPORTIONING CIRCUITRY
7. COOL PROPORTIONING CIRCUITRY
8. MACHINERY CONTROL CIRCUITS

In general, this order should be adhered to since the results that are to be achieved in a given section may be contingent upon having properly completed some procedure in a previous section. For instance, everything in sections 2 thru 8 assumes that section 1 has been properly completed. If this is not the case, any subsequent power supply adjustment might introduce significant errors in the adjustments previously accomplished in other circuitry.

Unless otherwise specified, the Operator's Controls are to be set as follows during this procedure:

R43	HEAT P ZONE	0%
R61	HEAT RESET	0%
R71	HIGH LIMIT	100%
R49	COOL P ZONE	0%
R52	COOL RESET	0%
R69	LOW LIMIT	0%
R39	PULSE RATE	120PPM
R81	MACH TIME OUT	5Sec
R26	DEV SPAN	±5%

After completing each segment of the procedure, the set up for that segment should be torn down unless the next segment calls for it to be retained.

Line power should be applied to terminals L, N and E of TB1 [Line, Neutral and Earth] from the variac, which should be set at 115vac unless otherwise specified in the procedure.

Terminals 9 and 10 of TB3 are normally shorted togather with a permanent jumper wire. Several parts of this procedure call for the temporary removal of this jumper. Always reconnect it when finished with those parts of the procedure, and be sure that it is properly connected before releasing the controller for stock, shipment or use.

1. D.C. POWER SUPPLY & REGULATOR CIRCUITS

The power supply system produces four dc potentials; +30v unregulated, -30v unregulated, +15v regulated and -15v regulated. Checks include:

1.1. Unregulated voltage levels
1.2. Regulated voltage levels
1.3. Line regulation
1.4. Load regulation
1.5. Nominal load current
1.6. Current limit operation
1.7. Oscillation, noise and transient response

1.1. Unregulated Voltage Levels

Connect the DVM between IC28-3 and ground. Set the line voltage [variac] at 115vac. The DVM should indicate +27v $\pm$4v. When the RJC circuit switches ON, this level will be reduced to +23v $\pm$2v. This happens 2 or 3 times per second.

Connect the DVM between IC29-5 and ground. With the line voltage at 115vac, the DVM should indicate -29v $\pm$2v. The operation of the RJC circuit will decrease this level only slightly, to about -26v.

1.2. Regulated Voltage Levels

Connect the DVM between IC28-8 and ground. Set the line voltage at 115vac. The DVM should indicate +15.00v. If not, adjust R84 until this indication is achieved.

Connect the DVM between IC29-8 and ground. With the line voltage at 115vac, the DVM indication should be -15.00v. If not, adjust R86 to produce this indication.

1.3. Line Regulation

Connect the DVM between IC28-8 and ground. The specified line voltage range for the controller is 90vac to 130vac. As the line voltage is varied between these limits, the DVM indication must remain within the limits of +14.98v to +15.02 v.

Connect the DVM between IC29-8 and ground. Repeat the above procedure for the -15v supply. The DVM indication must remain within the limits of -14.98v to -15.02v.

1.4. Load Regulation, Load Current & Current Limit

Connect the DVM across R82. The DVM indication will be about 180mV ±20mV. This represents a nominal load current of about 60mA. This level pulses with the operation of various circuits in the controller, but will remain within the above limits.

Connect the DVM between IC28-8 and ground. Connect a 330 Ohm resistor between the leads of the DVM. This increases the load current to about 100mA. When this is done, the DVM indication should remain within the limits of +14.98v to +15.02v.

Disconnect the resistor, and connect the DVM across R82. Now short IC28-8 to ground. The DVM indication should now rise to between 345mv and 405mv. This represents a current limit of between 115mA and 135mA.

Leave the short in place, and connect the DVM between IC28-8 and ground. The DVM indication will be about +.01v. When the short is removed, the indication will immediately recover to within the limits of +14.98v and +15.02v.

Connect the DVM across R88. The DVM indication will be about 275mv ±20mv. This represents a nominal load current of about 54mA. This level pulses with the operation of various controller circuits, but will remain within the above limits.

Connect the DVM between IC29-8 and ground. Connect a 330 Ohm resistor between the leads of the DVM. This increases the load current to about 100mA. When this is done, the DVM indication should remain within the limits of -14.98v and -15.02v.

Disconnect the resistor, and connect the DVM across R88. Now short IC29-8 to ground. The DVM indication should rise to between 590mv and 690mv. This represents a load current limit of between 115mA and 135mA.

Leave the short in place, and connect the DVM between IC29-8 and ground. The DVM indication will be about -.01v. When the short is removed, the indication will immediately recover to within the limits of -14.98v and -15.02v.

1.5. Oscillation, Noise & Transient Response

Connect the oscilloscope between IC28-8 and ground. The combined amplitude of any oscillation, noise and transient spikes should not exceed 20mv peak to peak.

Connect the oscilloscope between IC29-8 and ground. The same limits apply to this point; the composit signal not exceeding 20mv peak to peak.

2. REFERANCE JUNCTION COMPENSATOR CIRCUIT

The RJC circuit is a precision temperature control system designed to hold the temperature of the sensor circuit's second junction, or 'referance junction' very stable at about +160F. Checks include:

2.1. Referance temperature
2.2. Warm up time
2.3. Pulse rate
2.4. Referance temperature stability

2.1. Referance Temperature

Connect the Honeywell Potentiometer, Model 2736 or equal, between TB2-2 [-] and TB2-3 [+]. Disconnect any connection at TB2-1.

If necessary, allow a warm up period of sixty seconds prior to measuring this temperature with the potentiometer. The measured RJC temperature must be within the limits of +150F to +170F.

2.2. Warm Up Time

Connect the Potentiometer between TB2-2 [-] and TB2-1 [+], and set its EMF output at exactly +157.5F.

Connect the Precision Voltage Source, Thermotron 434004 or equal, between TB3-7 [-] and TB3-8 [+]. Use the E1 output and set it at 2.500v.

Useing the E2 output of the voltage source, calibrate the oscilloscope for a vertical gain of 100mv/cm. Then connect the oscilloscope across R27.

Connect a Thermotron 123005 deviation meter, else a jumper wire, between TB3-5 [-] and TB3-4 [+]. Set R26 fully cw.

Apply power to the controller and allow a warm up period of 120 seconds. Then set voltage source E1 as necessary to zero the oscilloscope. Turn the controller OFF and allow five minutes for the RJC element to return to ambient temperature.

Simultaniously turn the controller ON and start the stop watch, then observe the oscilloscope. Within 180 seconds the trace must come to within ±100mv of zero. This is about equal to ±.33F.

2.3. Pulse Rate

Note that the scope trace pulses at a rate of about one pulse per second. Useing the stop watch, measure the time required for ten pulses. The measured time must not exceed ten seconds.

2.4. Referance Temperature Stability

Retaining the above set up, trim the setting of voltage source E1 as necessary to zero the oscilloscope. Then observe the trace during a period of 120 seconds. During this time, no part of the trace may vary outside of the limits of ±100mv.

IMPORTANT NOTE

When the controller is equipped with RJC assy p/n 169001, this part must be shielded from drafts during all of the above tests. Preferably, the tests should be conducted with the cover properly installed on the controller. If this is not possible, the RJC assy itself may be covered useing a small plastic aerosol cap, or some other suitable device. When this is done, the cover must not physically contact the RJC element.

If this precaution is not observed, errors on the order of ±.5F will typically occur, and errors as large as ±2.5F might occasionally be observed.

These same precautions apply to the Portable Potentiometer, with respect to its terminals. Errors of the same magnitude can be produced by this source, since the temperature of the [-] terminal can change faster than the compensator in the instrument can respond. Keep this instrument out of drafts, and hands away from its terminals, while measurements are being taken. If possible, close its cover during these measurements.

3. AMPLIFIER & SCALEING CIRCUITS

The algebraic sum of the mj and rj emf's is fed to the amplifier and scaleing circuits. These circuits convert this low level emf signal to a voltage analog of temperature on a 'percent of span' basis: 0%/100% = 0v/+5v [≙-125F/+375F]. Checks include:

3.1. Zero point
3.2. Span point
3.3. Noise
3.4. Open sensor protection

3.1. Zero Point

Connect the Portable Potentiometer between TB2-2 [-] and TB2-1 [+].

Connect the DVM between TB3-10 and TB3-7.

Set the Potentiometer's EMF output at exactly -125F. At this time the DVM indication should be 0.00v. If not, adjust R13 as necessary to achieve this indication.

3.2. Span Point

Retaining the above set up, set the Potentiometer's output at exactly +375F. The DVM indication should now rise to exactly 5.00v. If not, adjust R19 as necessary to produce this reading.

If desired, linearity may now be checked as follows:

EMF Set	DVM Indication
-125F	0.00v
0	0.99
+100	1.92
+200	2.96
+300	4.09
+375	5.00

3.3. Noise

Connect the oscilloscope in parallel with the DVM leads. There should be no sign of oscillation or referance junction pulseing when the scope is set for a vertical sensitivity of 50mv/cm [AC input mode]. The level of white noise, or 'grass', should not exceed 20mv peak to peak, as seen with this set up [includes meter noise, scope noise, leadwire pick up, etc.].

3.4. Open Sensor Protection

IC2 is a non-inverting amplifier and will saturate if its input is allowed to float; this mechanism provides inherant TCBO protection for the controller via the failsafe limit circuits.

Retaining the above set up, disconnect one input lead at the Potentiometer. This should cause the DVM indication to rise to about +13.70v. In some cases the amplifier might

first swing to a negative value, then switch abruptly into positive saturation. This is an acceptable indication since the failsafe circuits will interpret anything less than zero, and anything more than +5v, as a fault condition.

Set the EMF output of the Potentiometer at exactly 157.5F and reconnect the input leadwire. The DVM indication should immediately return to +2.50v.

4. SET POINT BUFFER & DEVIATION AMPLIFIER CIRCUITS

The set point buffer accepts a 0v/+5v set point signal from remote sources. It offers a high dc input impedance to prevent loading of such sources, and reproduces the set point signal at its low impedance output.

The deviation amplifier compares the set point signal with the temperature signal, and produces an output current which is proportional to the differance, if any. This current is used to operate a deviation meter.

Checks include:

4.1. Set Point Zero
4.2. Set Point Span
4.3. Set Point Noise
4.4. Deviation Zero
4.5. Deviation Span

4.1. Set Point Zero

Connect a jumper wire between TB3-7 and TB3-8.

Connect the DVM between IC6-6 and ground. At this time the DVM indication must be 0.00v ±.005v.

4.2. Set Point Span

Connect a jumper wire between TB3-8 and TB3-11.

Connect an 8.119K resistor [7.5K + 619 Ohms] between TB3-7 and TB3-8.

Connect the DVM between IC6-6 and ground. The DVM should now indicate 5.12v. If not, adjust R22 as necessary to produce this indication.

4.3. Set Point Noise

Retaining the above set up, connect the oscilloscope in parallel with the DVM leads. There should be no sign of oscillation. The level of white noise should not exceed 20mv peak to peak, as seen with this set up [includes meter noise, scope noise, leadwire pick up, etc.].

4.4. Deviation Zero

Temporarily remove the jumper between TB3-9 and TB3-10. Connect a jumper between TB3-9 and TB3-7, and between TB3-8 and TB3-7.

Connect the DVM across R27, and turn R26 fully cw. The DVM indication should be within the range of ±30mv. This is about equal to ±.1F.

4.5. Deviation Span

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Set E1 at 5 .000v.

Connect voltage source E2 between TB3-7 [-] and TB3-9 [+]. Set E2 at 5.000v.

Connect the DVM across R27, and connect a jumper wire between TB3-4 and TB3-5.

Mechanically zero the knob of R26 at the ccw dot; set the knob at ±5%.

Now set E2 at 4.750v. This should produce a DVM indication of between -7.125v and -7.875v.

Next, set E2 at 5.250v. The DVM indication must now be within the range of +7.125v to +7.875v. This is about equal to ±1.25F.

NOTE

An out of tolerance reading here means that R26 is not within tolerance, and should be changed. The correct value may be calculated:

$$R26' = \frac{R26''\left(\frac{Em}{.25}\right)}{30}$$

where: R26' = correct value
R26''= original (measured) value
Em = voltage measured above

5. PROPORTIONING WAVE GENERATOR CIRCUITRY

The proportioning wave generator circuits generate two triangle waves. These waves are added to, and subtracted from, the set point signal in the cooling and heating sections of the controller, in order to develop its proportioning action. Checks include:

5.1. +7.5v referance
5.2. Low pulse rate calibration
5.3. High pulse rate calibration
5.4. Heating wave calibration
5.5. Cooling wave calibration

5.1. +7.5v Referance

Connect the DVM between IC8-3 and ground. Set R39 fully ccw.

The DVM indication will alternate between some positive level and zero. Adjust R31 as necessary to set the positive level at exactly +7.50v.

On the low part of the cycle, the DVM should indicate 0v ±2.5mv.

5.2. Low Pulse Rate Calibration

Connect the DVM between IC10-6 and ground. Turn R39 fully ccw, and mechanically zero its knob at the dot.

The DVM indication will alternate between negative and positive levels. Adjust R35 to set the positive level at 225.0mv.

Connect the oscilloscope to IC8-6. Useing the stop watch measure the exact time for twelve complete cycles, as displayed on the scope. This time should be exactly 120 seconds. If not, calculate a corrected setting for R35 as shown below, and readjust R35 accordingly.

$$E_2 = E_1 \left(\frac{T}{120}\right)$$

where: E_2 = correct setting in volts
E_1 = initial setting in volts [.225v]
T = measured time for 12 cycles

Useing the stop watch and the scope, verify that the time for six cycles is now exactly sixty seconds.

5.3. High Pulse Rate Calibration

Retaining the above set up, set R39 at 120PPM. Useing the stop watch and the scope, measure the exact time for 120 complete cycles. This time should be exactly sixty seconds. If not, proceed as follows:

Set R39 at 6PPM. Connect the DVM between the ccw (brn) end of R39 and ground. The DVM indication will alternate between negative and positive levels. Record the positive level and label it 'E_1'.

Now compute a corrected value for this voltage, then adjust R38 to provide this indication on the positive half cycle:

$$E_2 = E_1 \left(\frac{T}{60}\right)$$

where: E_2 = correct setting in volts
E_1 = measured initial setting in volts
T = measured time for 120 cycles

Return R39 to the 120PPM setting. Useing the stop watch and the scope, verify that the time for 60 cycles is now exactly 30 seconds.

5.4. Heating Wave Calibration

Connect the voltage source E2 between IC8-3 [+] and ground [-], and set E2 at 7.500v.

Connect the DVM in parallel with E2, and verify that the voltage at IC8-3 is now maintained at +7.5v, with no variation.

Now connect the DVM between IC20-3 and ground. Turn R43 fully ccw, and mechanically zero its knob at the dot, then set R43 at -5%.

At this time, the DVM should indicate exactly -250mv. If not, adjust R42 as necessary to produce this indication.

5.5. Cooling Wave Calibration

Retaining the above set up, connect the DVM between IC16-3 and ground.

Turn R49 fully ccw, and mechanically zero its knob at the dot, then set R49 at +5%.

At this time, the DVM should indicate exactly +250mv. If not, adjust R48 as necessary to produce this indication.

6. HEAT PROPORTIONING CIRCUITRY

The heat proportioning circuitry algebraically adds the set point signal, the proportioning wave and the reset signal. This sum is then compared with the temperature signal, and the heating output is energised whenever the temperature signal is less than the instantanious value of the composit set point signal, but not greater than a preset failsafe limit. Checks include:

6.1. Heat Set Point Zero
6.2. Heat Set Point Span
6.3. Heat Reset Accuracy
6.4. Heat Failsafe Calibration
6.5. Heat Output Signal & Proportioning

6.1. Heat Set Point Zero

Connect the DVM between IC19-6 and ground. Connect a jumper wire between TB3-7 and TB3-8.

Set both R43 and R61 fully ccw, then mechanically zero R61 at dot. Now set R61 at 0%.

The DVM should now indicate 0.00v. If not, adjust R60 as necessary to produce this indication.

6.2. Heat Set Point Span

Retain the above set up; DO NOT DISTURB the settings of R43 and R61 [0%].

Remove the jumper from TB3, and in its place connect the precision voltage source E1; TB3-7 [-] and TB3-8 [+]. Set E1 at 5.000v.

The DVM should now indicate +5.00v. If not, adjust R67 as necessary to provide this indication.

6.3. Heat Reset Accuracy

Retaining the above set up, set voltage source E2 at 4.950v, then lift the DVM lead from ground and connect it to the positive terminal of E2.

Set R61 at -1%. The DVM indication should now be within the range of from -10mv to +10mv.

Now set R61 at +5%, and set E2 at 5.250v. The DVM indication should now be within the range of from -25mv to +25mv. This is about equal to an accuracy of $\pm$2.5F at a reset value of about +25F.

6.4. Heat Failsafe Calibration

Connect the DVM between IC23-3 and ground. Turn R71 fully ccw, and mechanically zero its knob at the dot.

Now turn the knob to 100%. The DVM indication should now be 5.00v. If not, adjust R70 to produce this indication.

6.5. Heat Output Signal & Proportioning Action

Connect a 1.5K resistor between TB3-3 and TB3-6. Connect both the DVM and the oscilloscope across this resistor.

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Connect voltage source E2 between TB3-7 [-] and TB3-9 [+], temporarily removeing the jumper wire found between TB3-9 and TB3-10. Set E1 at 2.500v and also set E2 at 2.500v.

Now set R43 at -5% and R61 at 0%. Observe the scope, and trim the setting of R61 slightly to find the point at which the controller just stops pulseing [pulse just discernable in the noise]. At this point the control knob of R61 should still be at 0%. To facilitate scope observations, set R39 at 120PPM.

Set R71 at 75%. The DVM indication must now be within the range of from 0.00v to +0.50v. Proceed as follows:

E2 Setting	Scope Observation
2.490v	ON Time = 4%
2.450v	= 20%
2.400v	= 40%
2.350v	= 60%
2.300v	= 80%
2.260v	= 96%
2.250v	=100%

At this time the DVM indication must be within the range of from 4.00v to 6.00v.

Set E1 at 5.000v, and E2 at 3.700v. The DVM indication must now be 4.00v to 6.00v.

Set E2 at 3.800v. The DVM indication must now be within ±10mv of zero. This verifies the operation of the failsafe limit circuit.

Set R71 at 100%.

7. COOL PROPORTIONING CIRCUITRY

The cool proportioning circuitry algebraically adds the set point signal, the proportioning wave and the reset signal. This sum is then compared with the temperature signal, and the cooling output is energised whenever the temperature signal is greater than the instantanious value of the composit set point signal, and within the preset failsafe limits. Checks include:

7.1. Cool Set Point Zero
7.2. Cool Set Point Span
7.3. Cool Reset Accuracy
7.4. Cool Failsafe Calibration
7.5. Cool Output Signal & Proportioning

7.1. Cool Set Point Zero

Connect the DVM between IC15-6 and ground. Connect a jumper wire between TB3-7 and TB3-8.

Set both R49 and R52 fully ccw, then mechanically zero R52 at dot. Now set R52 at 0%.

The DVM should now indicate 0.00v. If not, adjust R51 to produce this indication.

7.2. Cool Set Point Span

Retain the above set up; DO NOT DISTURB the settings of R49 and R52 [0%].

Remove the jumper from TB3, and in its place connect the precision voltage source E1; TB3-7 [-] and TB3-8 [+]. Set E1 at 5.000v.

The DVM should now indicate +5.00v. If not, adjust R58 as necessary to provide this indication.

7.3. Cool Reset Accuracy

Retaining the above set up, set voltage source E2 at 5.050v, then lift the DVM lead from ground and connect it to the positive terminal of E2.

Set R52 at +1%. The DVM indication should now be within the range of from -10mv to +10mv.

Now set R52 at -5%, and set E2 at 4.750v. The DVM indication should now be within the range of from -25mv to +25mv. This is about equal to an accuracy of ±2.5F at a reset value of about -25F.

7.4. Cool Failsafe Calibration

Connect the DVM between IC22-2 and ground. Turn R69 fully ccw, and mechanically zero its knob at the dot.

Now turn the knob to 100%. The DVM indication should now be 5.00v. If not, adjust R69 to produce this indication.

7.5. Cool Output Signal & Proportioning Action

Connect a 1.5K resistor between TB3-2 and TB3-6. Connect both the DVM and the oscilloscope across this resistor.

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Connect voltage source E2 between TB3-7 [-] and TB3-9 [+], temporarily removeing the jumper wire found between TB3-9 and TB3-10. Set E1 at 2.500v and also set E2 at 2.500v.

Now set R49 at +5% and R52 at 0%. To facilitate scope observations, set R39 at 120PPM. Observe the scope, and trim the setting of R52 slightly to find the point at which the controller just stops pulseing [pulse just discernable in the noise]. At this point the control knob of R52 should still be at 0%.

Set R69 at 75%. The DVM indication must now be within the range of from 0.00v to +.50v. Proceed as follows:

E2 Setting	Scope Observation
2.510v	ON Time = 4%
2.550v	= 20%
2.600v	= 40%
2.650v	= 60%
2.700v	= 80%
2.740v	= 96%
2.750v	=100%

At this time the DVM indication must be within the range of from 4.00v to 6.00v.

Set E1 at 3.000v, and E2 at 3.700v. The DVM indication must now be within $\pm$10mv of zero.

Set E2 at 3.800v. The DVM indication must now be within the range of from 4.00v to 6.00v. This verifies the operation of the cool failsafe limit circuit.

8. MACHINERY CONTROL CIRCUITS

The machinery control circuits operate in conjunction with the cooling output to control the operation of mechanical refrigeration systems [compressors]. So long as the cooling output is active, or pulseing, these circuits hold the refrigeration system ON. This is accomplished by delaying the turn off time of the system with respect to the turn off time of the cooling output. The delay is adjustable over the range of 5 seconds to 120 seconds in order to accomodate the range of pulse rates and system operating characteristics. Checks include:

8.1. 120 Second Delay Calibration
8.2. Machinery Control Signal Output

8.1. 120 Second Delay Calibration

Connect voltage source E1 between TB3-7 [-] and TB3-8 [+]. Connect voltage source E2 between TB3-7 and TB3-9, observing the same polarity. Temporarily remove the jumper found between TB3-9 and TB3-10. Set E1 at 2.400v and set E2 at 2.500v.

Set the Operator's Controls as follows:

R43	HEAT P ZONE	0%
R61	HEAT RESET	0%
R71	HIGH LIMIT	100%
R49	COOL P ZONE	0%
R52	COOL RESET	0%
R69	LOW LIMIT	0%
R39	PULSE RATE	120PPM
R26	DEV SPAN	±5%

Turn R81 fully ccw and mechanically zero its control knob at the dot, then set this knob at 120 Seconds.

Connect a 1.5K resistor between TB3-1 and TB3-6. Then connect the oscilloscope across this resistor. The scope should indicate a positive level of about four volts.

Simultaniously, set E2 to a value of less than 2.300v and start timing with the stop watch. Now observe the scope presentation. Stop the watch when the trace falls. The trace should fall to zero in exactly 120 seconds. If not, proceed as follows.

Connect the DVM across R76. Record this voltage, which should be about 90mv, and label it 'E_1'. Now compute a corrected voltage as follows, and adjust R75 to produce this indication on the DVM.

$$E_2 = E_1 \left(\frac{T}{120}\right)$$

where: E_2 = correct setting in volts
E_1 = measured initial setting in volts
T = measured time delay

Now disconnect the DVM, and return the setting of E2 to 2.500v. Then repeat the above timing procedure to verify that the delay time is now exactly 120 seconds.

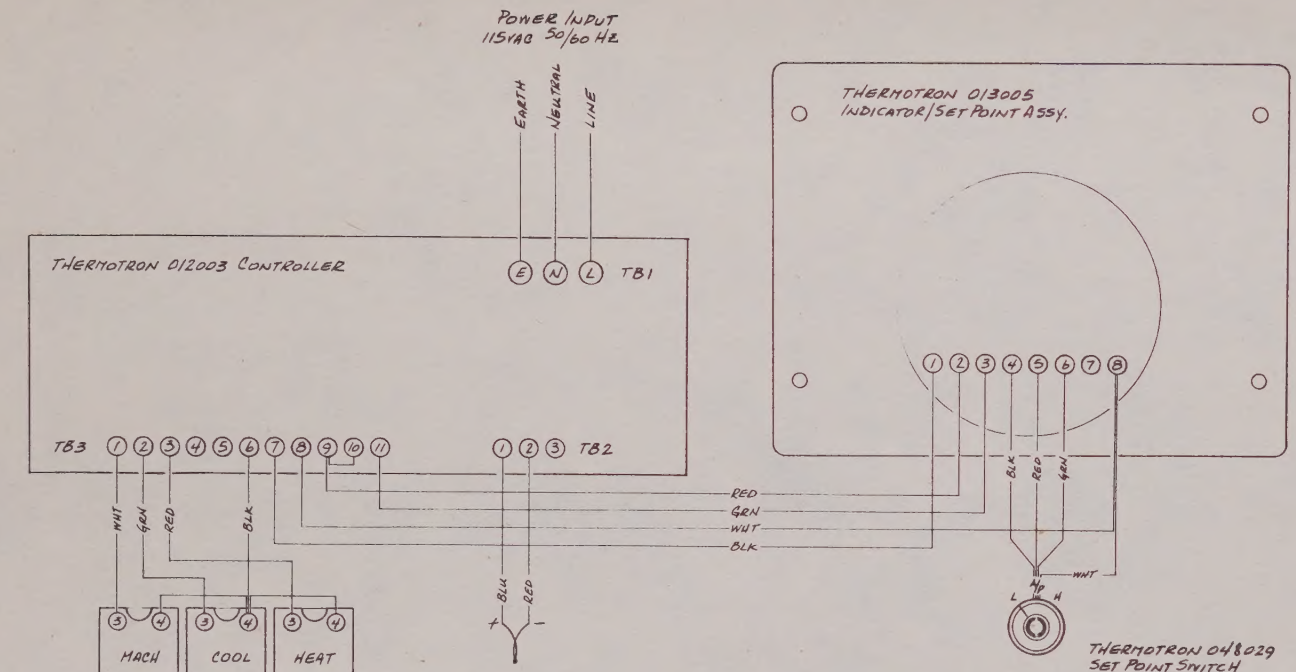
The minimum delay time can not be calibrated, and typically should be within 2.5 seconds to 5.0 seconds, depending upon finite componet values. This error will be stretched over the delay range, diminishing to zero at a setting of 120 Seconds.

8.2. Machinery Control Signal Output

Retaining the above set up, connect the DVM between TB3-1 and ground, or across the 1.5K resistor.

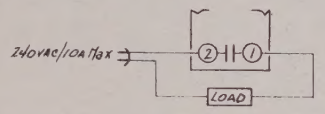
Set R81 at 5 Seconds, and voltage source E2 at 2.500v. The DVM indication should now be within the range of 4.00v to 5.50v.

Next, set E2 at 2.300v. Within five seconds the DVM indication should fall to within ±10mv of zero.



NOTES

1. BELDEN 8444 CONTROL CABLE RECOMMENDED FOR CONTROLLER-INDICATOR AND CONTROLLER-CRYDOM INTERCONNECTIONS.



TYPICAL CRYDOM WIRING

THERMOTRON CORPORATION
HOLLAND, MICHIGAN 49423

NO.	CHANGES	DATE	BY	CH'K'D	NO.	CHANGES	DATE	BY	CH'K'D

TOLERANCE	—
SCALE	—
MATERIAL	AS NOTED
FINISH	—
DRAWN BY	STARNER
DATE	2 APR 75
CHECKED BY	
DATE	
RELEASED BY	
DATE	

DESCRIPTION

TYPICAL NON-PROGRAMMED CONTROL SYSTEM WIRING INFORMATION

REF: 012003

470269

THERMOTRON

CORPORATION

Kollen Park Drive, Holland, Mich. 49423 U.S.A.
Phone (616) 392-1492 TWX No. 810-292-6164

1850 Lansdowne Ave.
Merrick, New York 11566
Phone: (516) 868-1800

8934 Mason Avenue
Chatsworth, California 91311
Phone: (213) 882-5030

24001 Southfield Rd.
Suite 106
Southfield, Michigan 48075
Phone: (313) 356-5010